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Effect of Relining with Different Composite Resins on the Push-out Bond Strength of Anatomical Fiber Posts to Root Canal Dentin

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ABSTRACT

Introduction: Relining fiber posts using composite resins helps the posts adapt to the anatomical space of the root canals. The aim of this study was to evaluate the effect of composite resin type on the push-out bond strength of anatomical fiber posts to intra canal dentin. **Methods and Materials:** Forty-eight bovine upper incisors were prepared for post space after root canal therapy and randomly divided in to six groups. Five different types of composite resin (GrandioSO, GrandioSO Heavy Flow, X-tra Fil, X-tra base and everX Posterior) were used for relining the prepared fiber posts. In the control group, the prepared post was cemented into the post space without relining. Cervical, middle and apical cross-sections were achieved from each root and push-out test was conducted at a crosshead speed of 0.5 mm/min. One sample from each group was scanned using a micro-CT scanner which provided views from the apical, middle and coronal thirds. Data were analyzed using Kolmogorov-Smirnov test, repeated measures ANOVA and post hoc tests using SPSS 17 ($P<0.05$). **Results:** Statistical analysis showed significant differences in terms of mean push-out bond strengths between different composite resin types and cross-sections ($P<0.001$). The mean push-out bond strength of the samples relined with Grandio SO composite resin (15.48±2.32) and X-tra Fil Bulk-fill composite resin (14.09±1.98) were significantly higher than that of other groups ($P<0.05$). The unrelined group had a mean push-out bond strength (5.94±1.45) which was significantly lower than that in other groups ($P<0.05$). In addition, there was a relationship between cross-sections and composite resin types ($P<0.05$). **Conclusion:** This *in vitro* study showed that the composite resins used for relining can affect the push-out bond strength to intra canal dentin based on their physical and mechanical properties.

Keywords: Dental Adhesion; Post Technique; Root Canals

Introduction

Endodontically treated teeth usually exhibit extensive destruction of the crown structure. When the remaining tooth structure does not provide adequate support for restorations, it is possible to use intra canal posts to achieve proper support and retention. Different materials and techniques are available for the reconstruction of severely destroyed teeth [1, 2]. Cast metallic posts have been used for several decades; however, prefabricated fiber posts are currently preferred due to their improved esthetic appearance and mechanical properties which are similar to those of the root dentin [3].

Fiber posts have a modulus of elasticity of 12 GPa which is close to that of natural dentin (18 GPa) and is different from that of metallic and ceramic posts [3, 4]. Stresses are concentrated at the apical third of the root in hard posts, resulting in a wedging effect [3]. Fiber posts are more flexible [1] and create a mono-block structure (dentin–cement–post) after being placed in the root canal, resulting in a homogeneous distribution of stresses [5, 6] and preventing vertical root fracture and re-infection of periapical areas [7].

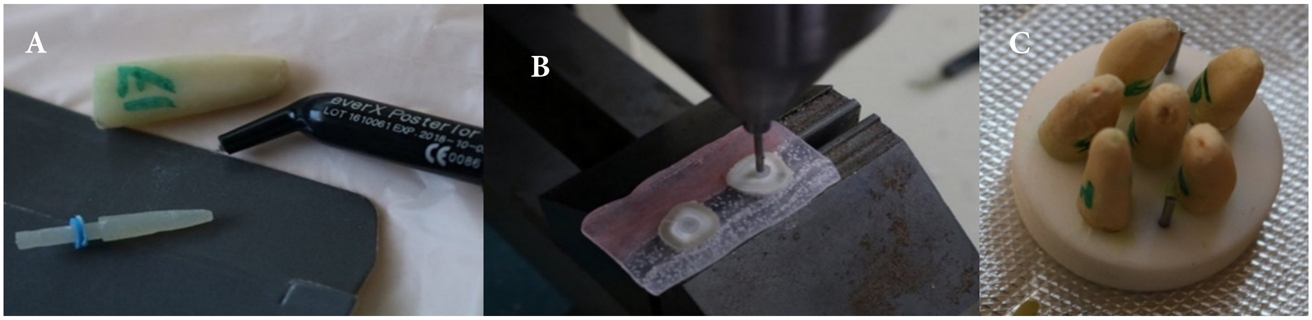

Figure 1. A) The relined fiber post; *B)* The push-out bond strength tests; *C)* Preparation of the samples for micro-CT examinations

The most important reason for the failure of the treatment with fiber posts is their debonding [8]. Debonding may result from the lack of adaptation between the prepared root canal andthe shape and diameter of the fiber post [4]. Some prefabricated fiber posts come with special drills for the creation of a specific space for them. There are some limitations in relation to the preparation of the root canal for its adaptation to the post; if the root canal is prepared excessively, the remaining root dentin will become thin, weak and susceptible to fracture [9]. In such cases, fiber post cementation techniques are considered to overcome the inconsistency of the post space [1, 2]. One of these techniques is to decrease the distance between the root canal walls and the fiber post by relining them with the use of composite resins before cementation. By relining posts, the odds of the structural deformity formation decrease in the cement layer because this technique helps the post adapt to the anatomical space of the root canals, resulting in a thinner layer of the cement [10]. Mechanical trapping of air bubbles within the bulk of the materials during the manipulation of the material affects the mechanical properties of the material and restoration longevity [11]. A thick cement layer increases the odds of bubble formation and debonding; while a thin and homogeneous cement layer decreases those risks [10]. Rocha *et al.* [12] evaluated the effect of anatomical customization of fiber posts on the push-out bond strength of self-adhesive resin cements. In that study, the bond strengths of the samples relined with composite resin were significantly higher than those of the samples that had not been relined. In that study a digital camera connected to a stereomicroscope was used to evaluate bubbles. There were significant differences in bubble formation between the samples and between the different segments of each root (coronal, middle and apical) [12].

In the past, destructive and two-dimensional techniques such as scanning electron microscopy (SEM), x-ray, determination of porosity with high mercury pressure and stereologic volumetric analysis were used to determine the adaptation accuracy [13]. In such destructive techniques, sectioning of the samples damages the polymeric matrix [14]. In addition, these techniques are not accurate in 3D and volumetric aspects [15]. Micro-CT is a non-destructive, fast and reliable technique for evaluation of the resin matrix [16].

Bulk-fill composite resins are a new group of restorative materials with modified structure and chemical composition for greater conduction of light and use in deeper areas. In some of these composite resins, the proportions of fillers with refractive indices close to that of the matrix have been increased, resulting in higher translucency and curing depth of composite resin. A change in the initiator system of composite resins is another technique to increase the curing depth. The presence of fiber glass in composite resin increases the strength of the composite resin, in addition to its translucency and conduction of light [17].

In most of the previous studies, only one type of composite resin was used for relining and adaptation of the fiber posts [2, 12, 18, 19]. The aim of this study was to evaluate the effect of composite resin type on the push-out bond strength of anatomical fiber posts to the intra canal dentin. The null hypotheses of the study were as follows: There was no significant difference in the push-out bond strength between relined and unrelined fiber posts, there was no significant difference in the push-out bond strength of fiber posts relined with different composite resins, and there was no significant difference in the push-out bond strength between different areas of the root canal.

Materials and Methods

Preparation of samples

Forty-eight freshly extracted bovine upper incisors were included in this *in vitro* study. The protocol of the study was approved by the Ethics Committee of Tabriz University of Medical Sciences (No: IR.TBZMED.VCR.REC.1397.206). A gauge (Buffalo Dental Manufacturing CD, Syosset, NY, USA) was used to measure the mesiodistal and buccolingual dimensions of roots on the buccal aspect at a distance of 2 mm

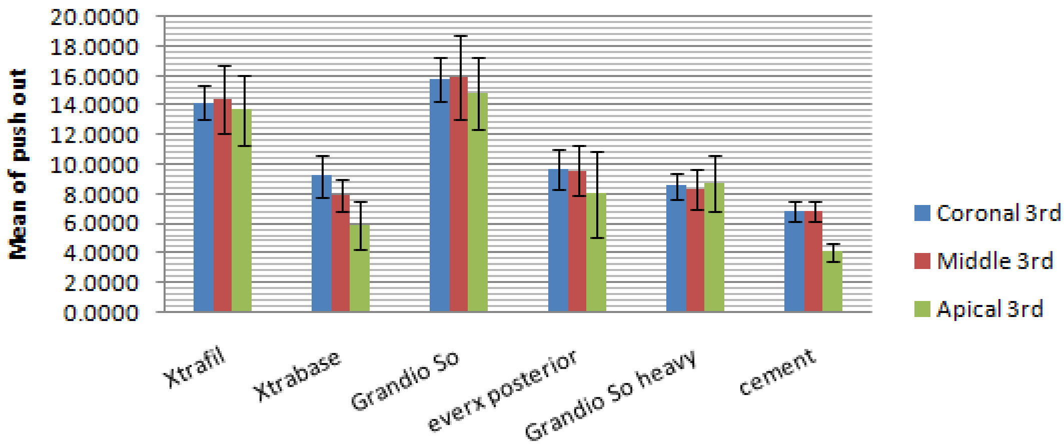

Figure 2. Error bar of push-out bond strength values in different study groups evaluated in terms of cross-section

from the CEJ. The mean acceptable dimensions were 6 mm in the mesiodistal and 8 mm in the buccolingual dimensions with a root length of 20 mm. Teeth with a deviation ≥ 20% from these dimensions were excluded. Teeth with any resorptions, cracks, caries, root fractures, abrasion and open apex were also excluded from the study [20]. The selected teeth were stored in phosphate-buffered solution until they were used in the study [21].

The teeth were numbered and radiographic examinations were carried out, followed by storage in 10% thymol solution during the study to prevent dehydration [20]. The tooth crowns were removed at CEJ with the use of a diamond disk (SP 1600 Microtome, Leica, Nu Block, Germany) to leave a root length of 16 mm [12]. The root canal space was prepared using the crown-down technique [20]. The coronal and middle thirds of the root canals were prepared with #2, #3 and #4 Gates-Glidden drills (Mani Inc, Tochigi, Japan), respectively, and the apical third was debrided with #40 master apical file (Dentsply Maillefer, Ballaigues, Switzerland); finally, a #70 file was used for final flaring of the root canals. During all the debridement procedures, the root canals were irrigated with 0.9% normal saline solution. The prepared root canals were obturated with gutta-percha (Tanari, Manacapuru, AM, Brazil) and AH-26 sealer (Densply DeTrey, Konstanz, Germany) up to 1 mm short of the root apex, using the lateral condensation technique. A radiographic technique was used to evaluate obturation quality. The samples were stored in an environment with 100% relative humidity so that the sealer would set [2]. Then the gutta-percha was removed from the root canal up to a length of 10 mm in order to prepare the post space. First, gutta-percha was removed with Gates-Glidden drills (#4 to #1) and the root canals were prepared with the drills recommended by the post manufacturer at a low speed [22]. The working length for the post space was 10 mm and 5 mm of gutta-percha was left at the root end [2, 20]. The smear layer was removed with 17% ethylenediaminetetraacetic acid (EDTA) (MD-Cleanser, META BIOMED, South Korea) and the root canals were irrigated with distilled water and dried with paper points [22]. The root canals were prepared up to a definite and identical size so that fiber posts of identical size could be used in all the root canals. Then for each root canal a fiber post (Exacto Translucent, Angelus Industria de Produtos Odontoloogicos Ltda, Londrina, PR, Brazil) proportional to the prepared root canal space was selected [18], tried within the root canal and then cleaned with alcohol (according to manufacturers' instructions) and silanized (Silano, Angelus Industria de Produtos Odontoloogicos Ltda, Londrina, PR, Brazil) for one min. The teeth and prepared posts were randomly assigned to six groups (n=8).

In the control group, the prepared post was cemented into the post space with the use of Panavia F2.0 (Kuraray Co., Osaka, Japan) dual-cured resin cement according to the manufacturer's instructions [23]. First, the primers A and B were mixed with each other at an equal proportion, applied to the coronal and root dentin areas with the use of a very small microbrush (Premium Plus, Yuen Long, N.T. HONG KONG) and gently air-dried after 30 sec; its excesses were removed with paper points. Then the pastes A and B were mixed with an equal proportion, applied on the post and carried into the root canal with the use of a lentulo spiral. The post was placed at the root canal center and light-cured with a light-curing unit (LITEX 695C Cordless, Curing, DENTAMERICA INC, CA, USA) at a light intensity of 500 mW/cm2 for 20 sec according to manufacturer's instructions [18]. In the remaining five study groups, a similar protocol was used to reline the prepared fiber posts, irrespective of the composite resin type. Five different types of composite resin were as follows: GrandioSO

(GC, Tokyo, Japan), GrandioSO Heavy Flow (GC, Tokyo, Japan), X-tra fil (Voco, Cuxhaven, Germany), X-tra base (Voco, Cuxhaven, Germany) and everX Posterior (Voco, Cuxhaven, Germany) (Table 1).

For relining procedure, first a hydrosoluble glycerin gel (Liquid Strip; Ivoclar Vivadent, Schaan, Liechtenstein), was used as an intracanal lubricant. Then the posts were silanized and a layer of each composite resin was placed on each relevant post in its non-polymerized state and carried into the root canal space (Figure 1A). Light-curing was carried out using an LED light-curing unit for 5 sec at a light intensity of 700 mW/cm2 according to the manufacturer's instructions. Then the post–composite resin complex was retrieved from the root canal space and light-curing was completed (for 20 sec) out of the root canal. The relined posts were irrigated and etched with 37% phosphoric acid (N Etch; Ivoclar Vivadent, Schaan, Liechtenstein) for 30 sec, rinsed again and air-dried. The root canals were irrigated with distilled water and dried with paper points. Then the posts were silanized for 60 sec and after drying, they were cemented in a manner similar to that in the first group [18].

Push-out bond strength test

Twenty-four h after cementing the fiber posts and storing them at 100% relative humidity, the root of each sample was sectioned perpendicular to the root long axis with the use of a diamond disk (SP 1600 Microtome, Leica, Nu Block, Germany) at a low speed under water cooling. Six 1-mm thick cross-sections were achieved from each root, which were categorized into three groups based on the root area: cervical, middle and apical, with two cross-sections for each area [5]. The universal testing machine (Hounsfield Test Equipment, Model H5K-S, Surrey, England) was used to carry out the push-out test at a crosshead speed of 0.5 mm/min with the use of a rod measuring 1 mm in diameter (Figure 1B). The machine applied the force in an apico-cervical direction until the post was separated from the sample [20]. The maximum force at failure was recorded in Newton and the bonding surface area was calculated using the formula below: $A=2r\pi\times h$ where $\pi=3.14$, r is the radius of the root canal space and h is the thickness of the cross-section in mm. The bond strength was calculated in MPa by dividing the force by the surface area [24].

Micro-CT

One sample from each group was placed in a base of teflon. Two nails were placed at the periphery of the circle as the first and second markers (Figure 1C). Then the samples were scanned using the micro-CT scanner (Lotus, NDK, Tehran, Iran) in the pre-clinical laboratory of Tehran University of Medical Sciences. The x-ray tube was operated at 118 µA and 85 kVp along with an 0.5-mm aluminum and copper filter at a resolution of 13.7 µm. The scanner revolved in a 360° circle around the samples and provided views from the apical, middle and coronal thirds [22].

Statistical analysis

The Kolmogorov-Smirnov test was used to assess the normality of data. Repeated measures ANOVA, one way ANOVA, post hoc Games-Howell and Sidak tests were used to evaluate the effect of composite resin type on the mean push-out bond strength in terms of the cross-sections tested. Statistical significance was set at 0.05. Data were analyzed with SPSS 17 (SPSS Inc, Chicago, IL, USA).

Table 1. The characteristics of the composite resins used

Materials	Manufacturer	Composite Type	Shade	Lot No.
X-tra fil	Voco, Cuxhaven, Germany	Bulk-fill paste composite	U	1618416
X-tra base	Voco, Cuxhaven, Germany	Bulk-fill flowable composite	A2	1747378
GrandioSO	Voco, Cuxhaven, Germany	Nano hybrid paste composite	A2	1740402
everX Posterior	GC, Tokyo, Japan	Paste composite with glass microfibers	U	1610061
GrandioSO Heavy Flow	Voco, Cuxhaven, Germany	Nano hybrid flowable composite	A2	1714124

Table 2. The means and standard deviations of push-out bond strengths in terms of cross-section and composite rein type

Composite resin type	Coronal	Middle	Apical	Total
	Mean (SD) MPa			
GrandioSO	15.74 (1.48) aA	15.87 (2.81) aA	14.83 (2.46) bA	15.48 (2.32)
X-tra fil	14.20 (1.10) aB	14.39 (2.33) aA	13.68 (2.35) bA	14.09 (1.98)
X-tra base	9.19 (1.38) aC	7.90 (1.03) aC	5.88 (1.56) bC	7.66 (1.90)
everX Posterior	9.70 (1.36) aC	9.58 (1.72) aB	8.00 (2.86) bB	9.09 (2.18)
GrandioSO Heavy Flow	8.50 (0.87) aC	8.29 (8.71) aB	8.71 (1.93) bB	8.50 (1.43)
Cement	6.83 (0.70) aD	6.83 (0.64) aD	4.05 (0.63) bD	5.94 (1.45)

Within groups, means with the same lowercase letter are not significantly different. Between cross-sections, means with the same uppercase letter are not significantly different (P=0.05)

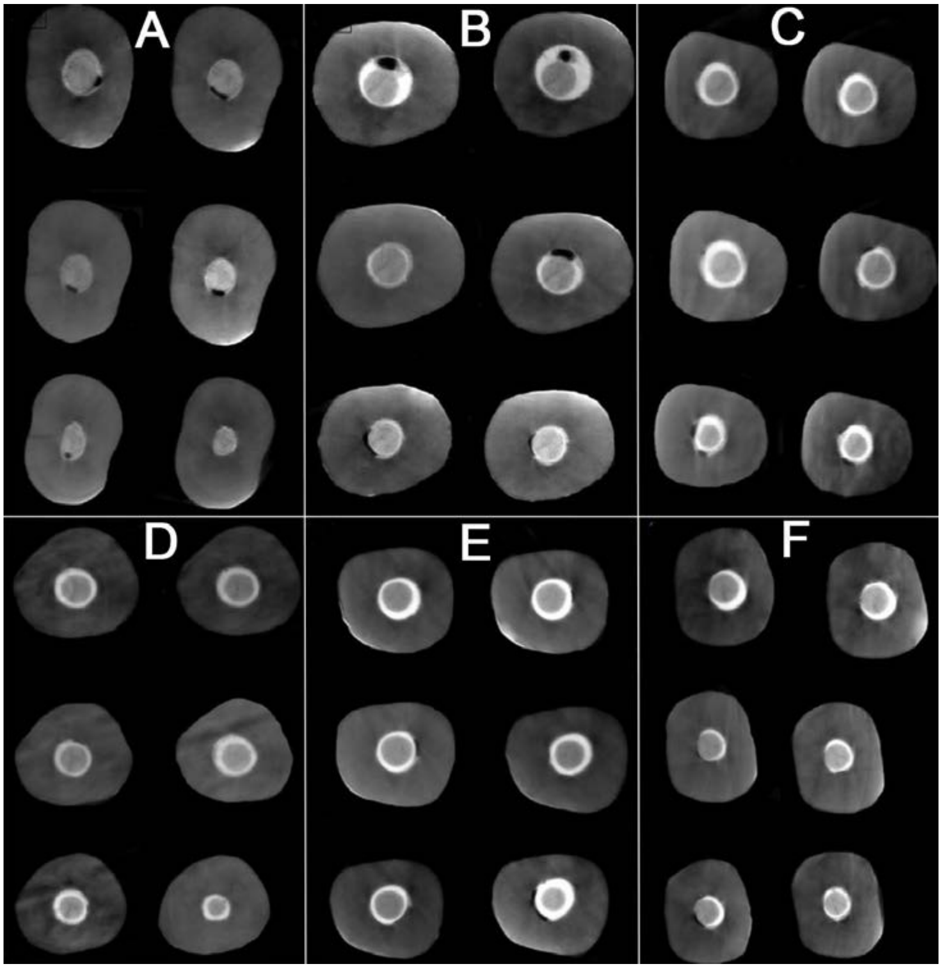

Figure 3. Micro-CT images in coronal (above), middle (middle) and apical (below) cross-sections separately for each group. Two cases have been selected from each cross-section. *A)* Unrelined fiber post; *B)* Fiber post relined with Grandio SO Heavy Flow composite resin; *C)* Fiber post relined with everX composite resin; *D)* Fiber post relined with Grandio SO composite resin; *E)* Fiber post relined with X-trfil composite resin;. *F)* Fiber post relined with X-tra base composite resin

Results

Push-out bond strength test

Table 2 presents the means and standard deviations of push-out bond strength values of different cross-sections and composite resin types. The results of the Kolmogorov-Smirnov test showed that the distribution of data was normal. Therefore, in order to investigate the study hypotheses, a parametric test was used (*P*>0.05).

The results of repeated measures ANOVA test showed significant differences in the mean push-out bond strengths of different cross-sections (*P*<0.001). There was a significant difference in terms of the mean push-out bond strength between the tested composite resin types (*P*<0.001). In addition, there was a relationship between cross-sections and composite resin types (*P*<0.05).

The results of Sidak post hoc test showed a significant difference in the mean push-out bond strength values between the coronal and apical thirds, with a lower mean push-out bond strength in the apical third compared to the coronal third (*P*<0.001). There was no significant difference in the mean push-out bond strength values of the middle third and the coronal and apical thirds (*P*>0.05). The results of Games Howell post hoc test showed that the mean push-out bond strength in the samples relined with GrandioSO composite resin (15.48±2.32) and X-tra Fil Bulk-fill composite resin (14.09±1.98) were significantly higher than that of other composite resin types (*P*<0.05). There was a significant difference in the mean push-out bond strength of the group relined with X-tra fil composite resin and all the other composite reins. The mean push-out bond strength in the X-tra fil composite resin was higher than that of other composite resins except for GrandioSO composite resin (*P*<0.05). The mean push-out bond strength in the unrelined group (5.94 ±1.45) was significantly less than that of other groups ($P<0.05$). There were no significant differences in the mean push-out bond strengths of the other groups ($P>0.05$) (Figure 2).

In order to evaluate the interaction between composite type and cross section, one way ANOVA tests were performed separately for each cross-section. The results showed a significant difference in terms of the mean push-out bond strength between the tested composite resin types ($P<0.05$). Games Howell tests were used as the post hoc tests. The results are provided in Table 2 (uppercase letters).

Micro-CT observations

The maximum number and size of voids were detected in the samples relined with GrandioSO Heavy Flow composite resin (Figure 3B), followed by the unrelined samples (Figure 3A). As seen in the figures, GrandioSO Heavy Flow composite resin has not properly surrounded the post and homogeneous adaptation has not been achieved. Despite the flow ability of this composite resin, more voids were detected in the cement layer. In this sample the voids were relatively similarly distributed in all the three coronal, middle and apical thirds. However, in the unrelined post group, more voids were detected in the coronal and middle thirds compared to the apical third. In this group, the cement layer was thicker in the coronal third compared to the apical third. The minimum amount of void and the maximum adaptation were detected in everX samples (Figure 3C). In the four everX, X-tra base, X-tra fil and GrandioSO groups, the apical third exhibited the maximum number of voids (Figures 3C-3F).

Discussion

In the present study, the push-out bond strength of the fiber posts relined with different composite resins was evaluated at different cross-sections of the root. In endodontically treated teeth, it is favorable to use materials with a modulus of elasticity similar to that of dentin (*e.g.* fiber posts) because these materials exhibit a more homogeneous stress distribution and decrease the odds of catastrophic fractures of the root [2]. Studies have shown that when the post does not have proper adaptation to the root canal, the cement layer becomes thick and susceptible to bubble formation, increasing the odds of fracture and post displacement. The risk of bubble formation is low in the cement layers that are thin and homogeneous [10, 25].

The results of the current study showed that the push-out bond strength was higher in the relined fiber posts compared to the unrelined ones; therefore, the first hypothesis of the study was refuted.

Despite the use of different materials, other studies have achieved similar results [2, 12, 19]. Rocha *et al.* [12] used a conventional nano-composite resin for relining and a self-adhesive cement for cementation of posts and reported higher bond strength values in relined samples [12]. Good proximity between the post and the root canal wall might result in a decrease in the cement layer and bubble formation, which might give rise to lower stress at the adhesive interface during polymerization shrinkage [19, 26]. Moreover, in the micro-CT observations, more voids and bubbles were found in the cement layer of the unrelined samples compared to the relined fiber posts with lower cement layer thickness.

In the present study, the push-out bond strengths of the fiber posts relined with different composite resins were significantly different; therefore, the second hypothesis of the study was refuted, too. In a study by Vano *et al.* [27], the microtensile bond strengths of fiber posts to different composite resin cores were not the same. In the present study, five different composite resins were used for relining fiber posts: two conventional nono-hybrid composite resins with different viscosities (GrandioSO and GrandioSO Heavy Flow), and two bulkfill micro-hybrid composite resins with different viscosities (X-tra fil, X-tra base and a composite resin reinforced with short fibers (everX Posterior). The highest push-out bond strengths for relined fiber posts were achieved by Grandio SOand X-tra Fil. Grandio SO is a nano-hybrid composite resin and has an 89 wt% of filler content (based on the manufacturer's data). The filler contents in everX, X-tra base and X-tra fil composite resins are 74.4%, 75% and 86%, respectively, based on a report by Leprince *et al.* [28]. In GrandioSO Heavy Flow, the filler content is 83% according to the manufacturer. Studies have shown that a higher filler content is associated with better mechanical properties of the composite resin; in this context, the flexural strength of GrandioSO composite resin has been reported to be 187 MPa based on the manufacturer's data. Leprince *et al.* [28] reported flexural strengths of 101.4, 110.5 and 130.7 MPa for everX, X-tra base and X-tra fil composite resins, respectively. The flexural strength of GrandioSO Heavy Flow composite resin has been reported to be 159 MPa by the manufacturer. A study by Li *et al.* [29] showed a direct relationship between the flexural strength of resin materials and their bond strength. Based on the manufacturer's data, GrandioSO has a modulus of elasticity of approximately 16.65 GPa, which is higher than those of other composite resins evaluated in the present study. The modulus of elasticity of everX, X-tra base and X-trafil composite resins have been reported to be 8.3, 7.4 and 9.4 GPa, respectively [28]. The modulus of elasticity of GrandioSO Heavy Flow has been reported to be 11.85 GPa based on the manufacturer's data. The modulus of elasticity of Angelus Exacto fiber post has been reported to be 19.3 GPa [30], with 18 GPa for dentin [28]. Therefore, GrandioSO has the greatest similarity to the dentin and the fiber post in terms of modulus of elasticity and possibly creates a more homogenous structure for distribution of stresses.

Another important consideration is comparison of the percentage of shrinkage after polymerization of these composite resins. The polymerization shrinkage of GrandioSO has been claimed to be 1.6% by the manufacturer. A study showed higher polymerization shrinkage for everX compared to X-tra fil whose polymerization shrinkage is approximately 1–1.16% [31]. On the other hand, a study by Leprince *et al.* showed almost similar polymerization shrinkage for everX and X-tra base composite reins [28]. A lower polymerization shrinkage of a composite resin results in the occupation of a larger space by the composite resin and a smaller space by the cement. Therefore, it is possible that in composite resins with lower shrinkage the cement layer becomes thinner, decreasing the possibility of bubble formation, which might affect the push-out bond strength. During the preparation of the samples, it appeared that it was easier to handle and shape the composite resins with higher viscosity compared to the two types of flowable composite resin. Despite the use of an intra canal lubricant and curing for just a few seconds before removing the relined fiber posts from the root canals, the odds of contamination of flowable composite reins with the lubricant were higher. Micro-CT images also revealed the maximum amount of voids in GrandioSO Heavy Flow composite resin compared to other composite resins. In addition, during the relining process, composite resins with higher viscosity better simulated the root canal shape. Micro-CT observations, too, confirmed the better adaptation of viscous composite resins to the root canal. All the factors discussed above might explain why GrandioSO Heavy Flow composite resin did not exhibit a high push-out bond strength despite its good mechanical properties. The results of micro-CT evaluations were less reliable due to the limitations of such evaluation as a result of a limited number of samples. In addition, since light-curing of the relined posts was completed after they were retrieved from the root canal and the thickness of composite resin around the posts was hardly >2 mm, the capacity of bulkfill composite resins for greater curing depth (around 4 mm) was not considered an advantage over other composite resins.

The evaluation of interaction between composite type and cross-section, showed almost similar patterns except for X-tra base in the middle and apical thirds. In these thirds, the mean push-out bond strength values of the X-tra base composite resin were less than those of other composite resins. As previously mentioned, everX and X-tra base composite resins have less filler contents and flexural strength values than other composite resins. Moreover, lower viscosity of X-tra base composite resin makes it difficult to handle and might lead to poor adaptation in areas with limited access like the middle and apical thirds and subsequently lower push-out bond strength.

The results of the present study showed that the push-out bond strength reached its minimum in the apical third; therefore, the third hypothesis of the study, which is related to the lack of difference in the bond strength between different root segments was refuted, consistent with the results of previous studies [2, 19]. In the root area, limitations for controlling the moisture, the lack of the possibility of direct visualization and control of the bonding process results in lower predictability of the bond strength [25]. These conditions are exacerbated by moving toward the apex. In this context, the tubular density and diameter of the tubules decrease toward the apex, which might affect the mechanism of micromechanical bonding [32]. In addition to the difficulty of access, it is difficult for the cement to flow in the apical area [26, 33]. Based on micro-CT findings, in the everX, X-tra base, X-tra fil and GrandioSO groups, there were more voids in the apical area, which might be one of the reasons for lower bond strength in these areas. However, in the unrelined post group, more voids were detected in the coronal and middle thirds compared to the apical third, which might be explained by the thicker cement layer in the coronal area. In addition, the bond strength in the apical area is affected by various factors other than voids, one of which is the longer distance of these areas from the tip of the light-curing unit, resulting in a decrease in its effect [26, 33]. In the present study a dual-cured resin cement was used; whose activation occurs chemically and by light. However, studies have shown that dual-cured resin cements that are activated only chemically do not reach a high level of hardness and conversion rate and that the performance of the cement significantly improves after light-curing [34-36]. Therefore, in the apical areas, ineffective polymerization of the resin cement due to the decrease in the light intensity results in lower conversion rate of resin monomers, preventing the formation of a homogeneous hybrid layer [37]. It appears that these events result in a lower bond strength in the apical areas. However, in a study by Rocha *et al.* the bond strength in the apical and middle thirds in relined samples was reported to be higher than that in the coronal area. In the study above, the number of cross-sections for each tooth was three (one section from each of the coronal, middle and apical thirds), which might not be adequate for the evaluation of the bond strength behavior. In addition, in the study above different materials were used incuding used conventional nano-composite resin for relining and a self-adhesive cement for cementation of the post [12].

In the present study, the fracture mode analysis was not assessed and micro-CT examinations for the presence of voids were carried out on only one sample from each group, which did not make it possible to make statistical comparisons between the groups and to determine the relationship between the presence of voids and the push-out bond strength. In addition, relining the fiber posts with low-viscosity composite resins encountered some limitations. Further studies are recommended in order to eliminate these limitations and compare the relining techniques with the use of other methods such as the use of dual-cured composite reins in association with fiber posts or reinforcing the root canal walls.

Conclusion

The results of the present study showed that an increase in the adaptation of fiber posts to the root canal through relining the fiber posts resulted in an increase in their push-out bond strengths. The composite resins used for relining can affect the push-out bond strength depending on their physical and mechanical properties. The push-out bond strength in the apical areas was lower than that in the coronal areas of the root canal.

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Conflict of Interest: 'None declared'.

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